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AN INFRARED IMAGING TRACKER FOR POINT AND  
NEAR POINT SOURCE TARGETS

by

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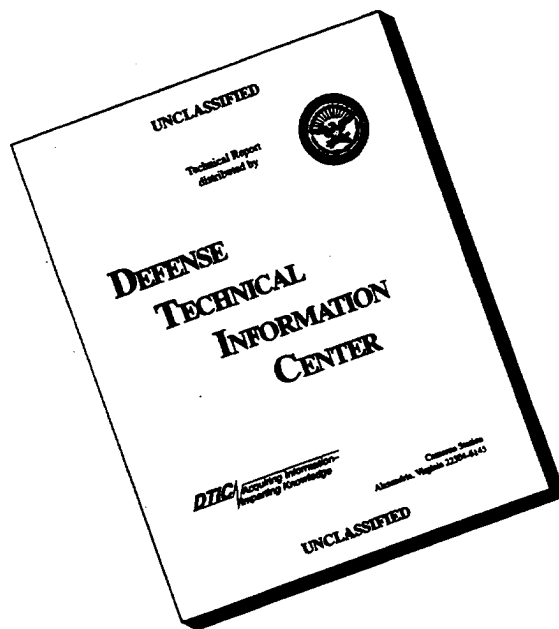


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## **An Infrared Imaging Tracker for Point and Near Point Source Targets**

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**Abstract:** This article introduces an infrared tracker used for point and near point source targets, provides a block diagram of tracker composition, and describes in detail a three-frame correlation multiple differentiation algorithm for target detection. Hardware results show that the design of this tracker is correct.

**Key Words:** Infrared imaging tracker for point and near point source targets, three-frame correlation multiple differentiation algorithm

### **1. Preface**

Multiple-mode tracking is necessary for imaging tracking technology, because no single tracking mode can adapt to complex, changing target and background conditions. Detection and acquisition of targets is generally carried out at long distances, and this exactly conforms to point and near point source conditions. Also, because the signal-to-noise ratio is very small at long distances, especially for small, slow-moving targets, suppression of background clutter is one of the issues that must be considered for this system. Even in situations where background clutter has been effectively suppressed, there is still a false alarm probability that cannot be ignored. Thus, further elimination of false targets in order to effectively acquire real targets is another critical signal-processing technology. This tracker employs three-frame correlation multiple differentiation algorithm technology whose purpose is to eliminate leftover false targets and, according to predetermined requirements, choose which tracking targets take precedence.

### **2. System Configuration**

Figure 1 gives a full description of the configuration of the system. After video signals from the thermal imaging system pass through A/D conversion, digitized wave filtering

suppresses background clutter. Acquisition and tracking states use different threshold partition algorithms, and can perform threshold coefficient selection according to *a priori* knowledge of different targets' backgrounds or on-the-spot training. One can see from the figure that switchover of acquisition and tracking states is executed by corresponding commands.

Differentiation algorithms are used in both acquisition and tracking states. In the latter, they are used to determine whether the target has been lost, and in the former, they are used to differentiate and select which targets to track. The differentiation algorithm used in acquisition will be discussed in detail below.

The normal tracking state is three-point quadratic prediction tracking. When target loss has been determined — for example, if the target is temporarily hidden from view — three-point linear memory tracking is implemented. After  $n$  seconds of delay, presently set at three seconds, if still in a target loss state, the system will switch over to the acquisition state and again carry out the detection and acquisition process.

In the tracking state, position error signals used for open-loop tracking simulation are output. At the same time, angle error signals can be output to the feeder system to carry out closed-loop tracking.

### 3. Three-frame Correlation Multiple Differentiation Algorithm

#### 3.1 Basic Algorithm

The following basic operations were carried out according to partitioned data  $(X_i, Y_i, S_i)$ , where  $S_i$  is the brightness of the  $i$ th pixel,

1) Potential target grouping: Adjacent pixels with position differences of  $\leq 2$  pixels are defined as one group (one of the potential targets), and the pixel number of the  $J$ th group is set as  $m_j$ .

2) Mean value of potential target brightness:

$$S_j = (\sum S_{j,i})/n_j. \quad (1)$$

3) Potential target centroid:

$$X_j = (\sum_{i=1}^n X_{j,i})/n_j, \quad (2)$$

$$Y_j = (\sum_{i=1}^n Y_{j,i})/n_j. \quad (3)$$

### 3.2 Correlation Operations

Adjacent three-frame (or, these three frames as an interval of  $n$  frames between every two adjacent frames, in order to more easily distinguish the target's state of motion) data are used to carry out the following correlation operations:

1) Pixel data correlation:

$$|n_j(K-2) - n_j(K-1)| \text{ and } |n_j(K-1) - n_j(K)| < 2. \quad (4)$$

2) Brightness correlation (rough):

The goal of the above correlation operations is to first eliminate non-correlated false targets.

3) Relative rest or parallelism to the axis of sight is correlated to the stability of the target in motion:

$$\begin{cases} |X_j(K-2) - X_j(K-1)| \text{ and } |X_j(K-1) - X_j(K)| < 2\text{pixel}, \\ |Y_j(K-2) - Y_j(K-1)| \text{ and } |Y_j(K-1) - Y_j(K)| < 2\text{pixel}. \end{cases} \quad (5)$$

This correlation operation helps eliminate random interference.

4) Correlation of moving target:

Definition:

$$\begin{aligned} X_j(K-2) - X_j(K-1) &= \Delta X_{j,1} \\ X_j(K-1) - X_j(K) &= \Delta X_{j,2} \end{aligned} \quad (6)$$

Similarly, a definition like that above can be made for component  $Y$ .

Range of speed of target motion is limited to:

$$|\Delta X_{j,1}| \text{ and } |\Delta X_{j,2}| < 20 \text{ pixel} \quad (7)$$

$$\text{and } |\Delta Y_{j,1}| \text{ and } |\Delta Y_{j,2}| < 20 \text{ pixel} \quad (8)$$

Equidirectional motion determination:

$$\Delta X_{j,1} \text{ and } \Delta X_{j,2} \text{ ①符号相同} \quad (9)$$

$$\Delta Y_{j,1} \text{ and } \Delta Y_{j,2} \text{ ①符号相同} \quad (10)$$

Key: (1). Symbols are the same

Orbit correlation determination: Where conditions (7)—(10) are fulfilled, we further require

$$|\Delta X_{j,1}| - |\Delta X_{j,2}| < 2 \text{ pixel} \quad (11)$$

$$\text{and } |\Delta Y_{j,1}| - |\Delta Y_{j,2}| < 2 \text{ pixel} \quad (12)$$

The above algorithms can effectively reduce the amount of operations and differentiate near-uniform motion targets. This conforms to long-distance detection and acquisition conditions.

Determination of fastest and slowest motion speed of moving target: Where conditions (7)—(12) are fulfilled, let

$$\begin{aligned} (|\Delta X_{j,1}| + |\Delta X_{j,2}|) / 2 &= V_{x,j} \\ (|\Delta Y_{j,1}| + |\Delta Y_{j,2}|) / 2 &= V_{y,j} \\ V_j &= V_{x,j} + V_{y,j} \end{aligned} \quad (13)$$

to derive

$$N_j = \text{Max}(V_j)$$



According to the above criteria, it is possible to program the priority of targets for acquisition. For example, it is possible to first acquire the target with the highest speed of motion, or a relatively motionless target from among multiple targets. If there is more than one relatively motionless target, it is possible to program selection of the smallest target or the one with the greatest brightness for tracking.

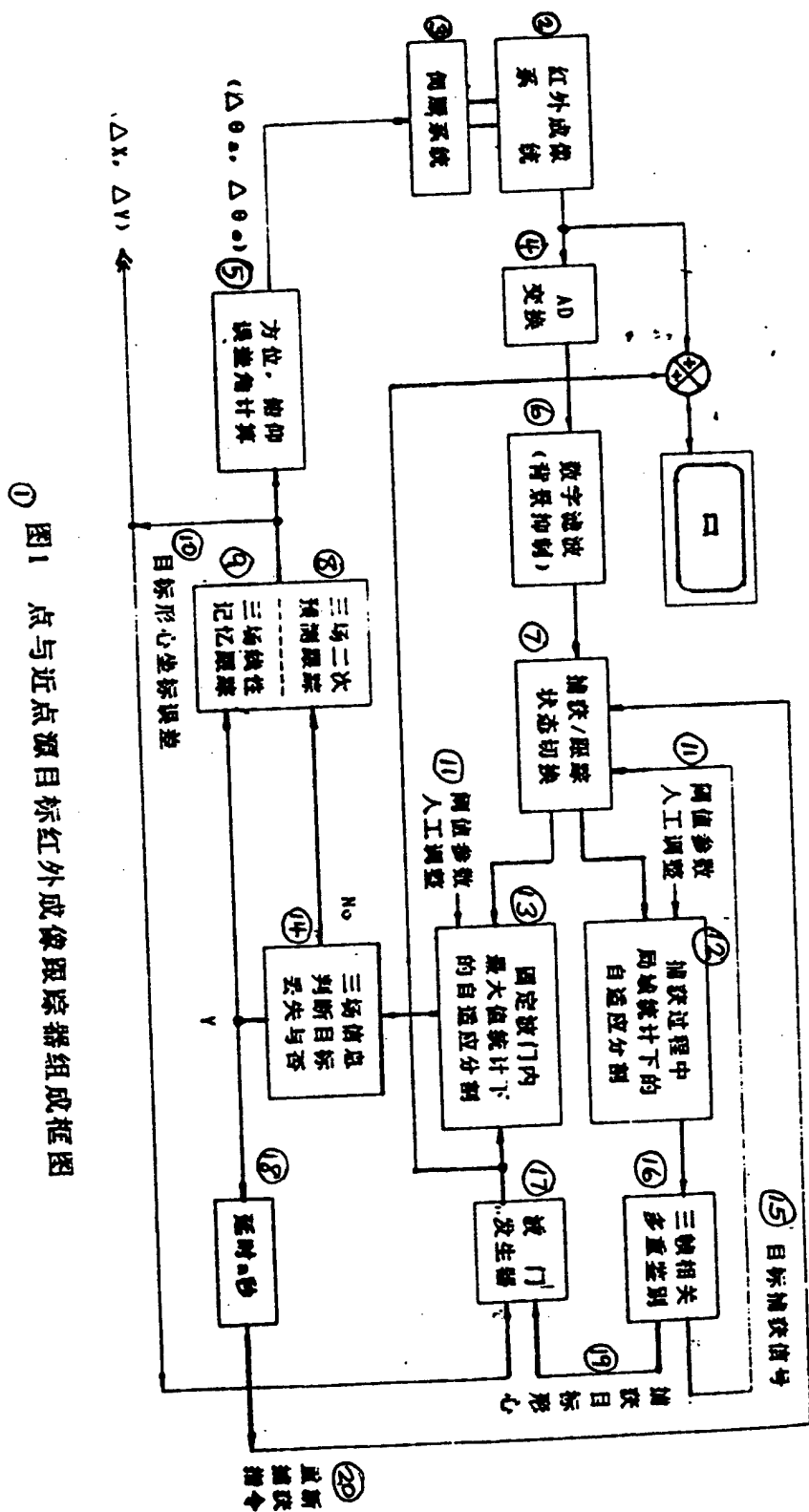
#### 4. Discussion

Where signal-to-noise ratio is very low, even if background clutter suppression and multiple-frame correlation multiple differentiation technology are applied, false targets may still exist. In addition to further improving wave filtering technology and hardware technology, artificial interference technology can also be employed. Consideration was given to this technology during the design of this tracker, and a high-resolution touch-screen display device would be an ideal choice. A more fundamental development direction, however, is multiple-sensor fusion of target-priority artificial intelligence decision-making technology with system fusion technology.

#### 5. Conclusions

This article introduces a tracker that uses specially designated background clutter suppression wave filter technology and three-frame correlation multiple differentiation technology. This tracker has already been realized in hardware form. The performance of the hardware tracker and ring opening tracking results show that the tracker's design and relevant algorithms are correct. Following further perfection and improvements to reliability, it can be applied to corresponding engineering systems.

Note: During the formulation of this project, Liu Zhili, Yan Jun, Hao Wenhui, and other comrades participated in discussions.



**Key:** (1). Figure 1. Point and near point source target infrared imaging tracker configuration block diagram. (2). Infrared imaging system. (3). Feeder system. (4). AD conversion. (5). Position and pitch error angle calculation. (6). Digital wave filter (background suppression). (7). Switchover between acquisition and tracking states. (8). Three-field quadratic prediction tracking. (9). Three-field linear memory tracking. (10). Target centroid coordinate error. (11). Artificial adjustment of threshold parameters. (12). Adaptive partition with local statistics during acquisition. (13). Adaptive partition with maximum-value statistics inside fixed wave door. (14). Three-field determination of whether or not target is lost. (15). Target acquisition signal. (16). Three-frame correlation multiple differentiation. (17). Wave door generator. (18).  $n$ -second delay. (19). Target acquisition centroid. (20). Reacquisition command.